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ABSTRACT

Previous research has cast doubt on children's ability to use specified evidence when making causal inferences, or, indeed, to differentiate between the specified evidence and their own preconceptions, or "prior theories." The present study continues previous work by distinguishing between children's reasoning in conditions where sufficient or insufficient evidence is supplied, and by determining whether children appropriately change or maintain judgments when they experience reversals from sufficient evidence to insufficient evidence on a similar task. The present study extends previous work by: (1) the use of task variation designed to overcome causal reasoning compelled by the pattern of the data within task presentations; (2) the analysis of differences in reasoning between 7-year olds and 9-year olds, rather than only the latter; and (3) the utilization of both a multiple-choice format and a free-response format to minimize the "can't tell" responses. The subjects were 24 children, 12 of each age group, enrolled in a university-sponsored elementary school summer camp program. Each subject received eight tasks while individually interviewed and tape-recorded. Overall performances, in both the sufficient and insufficient evidence conditions, support the previous finding that children first relate their judgments to specified evidence when that evidence is sufficient, and only afterward might they extend this procedure to conditions where the evidence is insufficient. (JJK)

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Scientific reasoning: Elementary schoolers' evidence based reasoning

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For presentation at the Annual Meeting of AERA, 1991, Chicago

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Scientific reasoning: Elementary schoolers' evidence based reasoning

Scott Lewis and Joseph Becker

Research has cast doubt on children's ability to use specified evidence to make causal inferences or even to differentiate between the specified evidence and their preconceptions, or "prior theories" (Kuhn, Amsel & O'Loughlin, 1988). Kuhn et al. found that adults and school children were influenced by their preconceptions ("prior theories"), generally failing to restrict their reasoning to the specified evidence and to treat it in a strictly logical manner. Kuhn et al. gave their subjects complex problems. Adequate solutions required the subjects to coordinate as many as four binary antecedent variables and an outcome variable.

Kuhn et al.'s data indicated limitations on their subjects' causal reasoning both when the evidence was sufficient (subjects generally failed to restrict their reasoning to the specified evidence and to make the warranted inferences) -- and when the evidence was insufficient (subjects insisted on making causal judgments designating variables as effective or ineffective). These results suggest important limitations on student's reasoning, especially when considered in conjunction with research emphasizing the strong influence of prior theory on school children's learning of science (Osborne and Freyberg, 1985). However, using the same basic paradigm as Kuhn and her colleagues, we have argued for important competencies in causal reasoning in children even younger than those studied by Kuhn et al. (Becker and Lewis, 1990).

We presented data indicating that when simple problems involving a single variable were used (subjects had to judge which of two products were better on the basis of evidence of the performance of each), elementary school children from grade 3 through 6 differentiated between cases in which there was sufficient evidence and cases in which there was not. Although these subjects persisted in using their preconceptions and made causal judgments unwarranted by specified evidence when the evidence was insufficient, they used the evidence correctly to make appropriate causal judgments when the evidence was sufficient. Furthermore when subjects first made causal judgments in insufficient evidence conditions, they subsequently overwhelmingly changed or maintained these judgments as appropriate when given sufficient evidence. The present study extends that work in three ways -- while continuing (a) to distinguish between children's reasoning in two conditions: the insufficient evidence condition and the sufficient evidence condition, and (b) to determine whether when children are given sufficient evidence they appropriately change or maintain judgments which they previously gave when the evidence was insufficient.

First, while pointing to important competencies in causal reasoning for elementary school children, the previous study was limited by a feature of the data given to the subjects. In that study, we presented subjects with evidence about an advertised product and a regular (not advertised) product and asked them to use the evidence to determine whether the company was justified in claiming that the advertised product was superior to the regular product. For each product subjects were told the number of trials producing a relatively good outcome and the number of trials producing a relatively bad outcome. However, the evidence about the advertised product was always that 50% of the trials gave relatively good outcomes and 50% of the trials gave relatively bad outcomes. The subjects may have categorized each product as good (the product has more trials with relatively good outcomes than trials with relatively bad outcomes), bad (the product has more trials with relatively bad outcomes than trials with relatively good outcomes), or indifferent (the product has equal number of trials with each outcome). The subjects

may then have reached adequate judgments based on a comparison of the categorizations they achieved for the two products.

This raises the possibility that the children might not be able to reason adequately in cases where the majority of the trials of each product gives a relatively good outcome, or a majority of the trials of each product gives a relatively bad outcome. For example, the good-bad- indifferent categorization strategy would not be adequate for dealing with the following case: For Superseeds, 7 trials yielded plants 24" high and 3 trials yielded plants 12" high., whereas for regular seeds, 9 trials resulted in 24" plants and 1 trial resulted in a 12" plant. Accordingly, in the present study we used two variants of the task: a variant which contained **one 50-50 product**, and a variant which contained **no 50-50 product**.

Second, the youngest subjects examined in our previous study were 9 year olds, and as indicated, these children exhibited significant competencies. In the present work, we examined the reasoning of 9 year olds and 7 year olds to see what differences there are, if any, in how the two age groups reason about these problems.

Third, in our previous work, we used a free response format, and found that "can't tell" responses were rare. Kuhn and her colleagues explicitly offered their subjects three choices for their judgments including a "maybe" (or "can't tell") response, and also found that "can't tell" responses were rare. However, it is possible that the multiple choice format may elicit more "can't tell" responses (when the evidence is insufficient) for the simple tasks used by Becker and Lewis. This might be the case if children avoided the "can't tell" responses in these problems more for social reasons (authority of experimenter, social conventions against admission of not having a determinate answer etc.) than because of limitations in their understanding of the relation of evidence to causal judgments. Therefore, in the present work we used two formats: a **multiple choice format** and a **free response format**.

Method

Subjects

Subjects were 24 children enrolled in a university elementary school summer camp program: 12 7-year-olds (mean age: 7 years 2 months) and 12 9-year-olds (mean age: 9 years 5 months).

Tasks

Each problem consisted of an insufficient evidence condition followed by a sufficient evidence condition. Insufficient evidence condition: Subjects were told that a company claimed that it had a super product which was superior to the corresponding regular product. Subjects were presented with the number of trials of the super product which had a relatively good outcome and the number of trials which had a relatively bad outcome. The evidence about the super product varied across problems from cases where the majority of the trials gave good outcomes to cases where the number of trials which gave good outcomes equalled the number of trials which gave bad outcomes to cases where the majority of the trials gave bad outcomes. In the multiple choice format, subjects were asked a question of the form: "Do you think the Superseed Company is right when they say that Superseeds grow faster than regular seeds, or do you think you can't tell or do you think they are wrong?" In the free response format, subjects were asked a question of the form: ""Do you think the Superseed Company is right when they say that Superseeds grow faster than regular seeds?" Subjects were asked to justify their judgments. Sufficient evidence condition: Subjects were presented with the number of trials of the regular product which had a relatively good outcome and the number of trials which had a relatively bad outcome. The evidence about the regular product also varied across problems from a majority of trials having good outcomes to cases where the number

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of trials having good outcomes equalled the number of trials having bad outcomes to a majority of trials having bad outcomes. Subjects were again probed for judgments and justifications. When the majority of trials of both products gave relatively good outcomes (and when the majority of trials of both products gave bad outcomes), the evidence still indicated that one product was superior to the other (one product still had a better record than the other).

Administration

Subjects were interviewed individually and the interviews were tape-recorded. Each subject received 8 problems (presented pictorially and verbally at the same time). Each subject received 4 problems in which the evidence showed the advertised product to be superior and 4 problems in which the evidence showed the regular product to be superior. Each subject received 4 problems in the "one 50-50 product" variant and 4 problems in the "no 50-50 product" variant. Half the subjects in each age group first received 4 "one 50-50 product" problems and then received 4 "no 50-50 product problems. The rest of the subjects received the reverse order. Half the subjects in each age group first received 4 problems in the multiple choice format and then received 4 problems in the free response format. The rest of the subjects received the reverse order.

Results and discussion

Sufficient evidence condition

In the sufficient evidence condition, there was no significant difference between performance in the "one 50-50 product" task variant and the "no 50-50 product" task variant for either the 7 year olds or the 9 year olds. Both age groups taken together had a mean of 2.7 correct (out of 4 problems) in the "one 50-50 product" task variant and a mean of 3.0 correct in the "no 50-50 product" task variant. This indicates that the children who are reasoning using the evidence are not restricted to the good- bad-indifferent categorization strategy. They seem to directly compare the data for the two products in solving the "no 50-50 product" task variant.

In the sufficient evidence condition, the 9 years olds gave significantly more correct judgments. For 9 year olds the mean number of correct judgments -- identifying whether the advertised product was better than the regular product -- (out of 8 problems) was 6.6, and for 7 year olds it was 4.9 (t test, $p < .05$). Especially in view of the possibility of getting one third to half the problems correct on the basis of chance (depending on whether or not can't tell responses are considered as a possibility), we consider that this result indicates that the 9 year olds are reasoning better than the 7 year olds.

Insufficient evidence condition

In the insufficient evidence condition, children tended not to give "can't tell" responses. The means were 2.1 and 2.5 for the 7 and 9 year olds respectively (n.s.). Relative to previous work, these are high levels of can't tell responses (approx. 30%). However, for 7 year olds only 32% (8 out of 25) and for 9 year olds only 43% (13 out of 30) of these responses were accompanied by an adequate justification (i.e., need for evidence about the regular product). Can't tell responses with adequate justifications were given by 4 of the 12 7-year-olds and by 6 of the 12 9- year-olds. However, no 7 year old gave more than 2 such responses out of 8 problems, and no nine year old gave more than 3. For 7 year olds there was a tendency to give such responses more in the last 4 problems than in the first 4 (children gave 7 out of 8 of such responses in the last 4 problems they received). For 9 year olds there was no such tendency (children gave 7 out of 13 such responses in the last 4 problems they received).

The multiple choice format elicited more "can't tell" responses than the free response format. This is particularly evident when comparing the responses in each condition when that condition was given first -- that is, each child's responses to the first four questions given to that child. The percentage of "can't tell" responses (with and without adequate justifications) for 7 year olds in the free-response-format-first condition was 8% (2 out of 24) and in the multiple-choice-response-format-first condition it was 33% (8 out of 24). For 9 year olds it was 17% (4 out of 24) and 33% (8 out of 24) respectively. The level of "can't tell" responses in the multiple choice format is equal to the chance expectation for the multiple choice format. This seems to indicate that the multiple choice format helped the children overcome any social inhibition they may have had against giving a "can't tell" response. On the other hand, the chance level of the "can't tell" responses in the multiple choice format seems to indicate that the children do not have a strongly conceptual understanding of the appropriateness of the "can't tell" response. This is consistent with the relative scarcity of adequate justifications in each format.

The number of "can't tell" responses with adequate justifications was equal for the two formats. The low number precludes any conclusion from this -- however, this finding is consistent with the notion that when children have developed a strong conceptual understanding of the appropriateness of the "can't tell" response, they overcome the social inhibitions against giving a "can't tell" response.

Changes in judgments

Since children tend to give a definitive response in the insufficient evidence condition (i.e., a response which claims one of the two products to be better than the other), the possibility arises that their success in determining the correct judgment in the sufficient evidence condition is a function of whether they need to change or to maintain the judgment they (inappropriately) gave in the insufficient evidence condition. On the one hand, children might maintain their responses irrespective of the evidence due to the strength of their preconceptions. On the other hand, children might change their responses irrespective of the evidence because they regarded the repetition of a question as an invitation to change their judgments, as has been claimed to be the case in children's failure in Piagetian conservation tasks (McGarrigle & Donaldson, 1974).

For the 7 year olds, of the 70 definitive responses 34 needed to be changed and 36 needed to be maintained to produce correct judgments in the subsequent sufficient evidence condition. The children appropriately changed 14 out of the 34 (41%) and appropriately maintained 27 out of the 36 (75%). For the 9 year olds, of the 65 definitive responses 41 needed to be changed and 24 needed to be maintained to produce correct judgments in the subsequent sufficient evidence condition. The children appropriately changed 32 out of the 41 (78%) and appropriately maintained 21 out of the 24 (88%). Thus, the seven year olds tended appropriately to maintain their previous judgments relatively more often than appropriately to change their judgments. There is a much slighter tendency in the same direction for the 9 year olds. However, it is clear that the 9 year olds success in the sufficient evidence condition is not due to a bias either to maintain or to change their initial judgment irrespective of the evidence.

These conclusions held separately for each task variant. However, the bias of the 7 year olds not to change their previous judgments appeared stronger in the "one 50-50 product" task variant than in the "no 50-50 product task variant. In the "one 50-50 product" task variant, the 7 year olds appropriately changed 5/18 (28%) and appropriately maintained 14/19 (74%) of the definitive judgments they had made in the insufficient evidence condition. The 9 year olds, appropriately changed 11/16 (69%) and appropriately maintained 13/16 (81%) of the definitive judgments they had made in the insufficient evidence condition. In the "no 50- 50 product" task

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variant, the 7 year olds appropriately changed 9/16 (56%) and appropriately maintained 13/17 (77%) of the definitive judgments they had made in the insufficient evidence condition. The 9 year olds, appropriately changed 21/25 (84%) and appropriately maintained 8/8 (100%) of the definitive judgments they had made in the insufficient evidence condition.

Summary

The 9-year-old elementary school children reasoned well on simple problems which have sufficient evidence available to make a definitive judgment. The 9 year olds gave correct judgments in 82% of the sufficient evidence conditions. Furthermore, they were not restricted to cases where the strategy of categorizing each product as good, bad or indifferent is effective. They reasoned well in cases where both products had a majority of trials having a relatively good outcome or both products had a majority of trials having a relatively bad outcome. The 9 year olds' success in the sufficient evidence condition was not associated with a bias to maintain or change their previous judgments irrespective of the evidence. The 7 year olds reasoned less systematically, judging only 61% of the problems correctly in the sufficient evidence condition.

When the evidence was insufficient, both 7 and 9 year olds only occasionally refrained from making judgments. The level of "can't tell" responses in the multiple choice format is equal to the chance expectation. It seems that the multiple choice format helped the children overcome any social inhibition they may have had against giving a "can't tell" response. On the other hand, the children seem not to have a strongly conceptual understanding of the appropriateness of the "can't tell" response. In the insufficient evidence condition, the children were more likely to give a "can't tell" response when it was offered to them as one choice in a multiple choice format, but gave very few adequate justifications for "can't tell" responses in both the multiple choice and the free response formats.

Taken together the performances in the sufficient and insufficient evidence conditions in the present study support Becker and Lewis' (1990) finding that children first relate their judgments to specified evidence when there is sufficient evidence, and only later may extend this to conditions where the evidence is insufficient. These findings are important for the light they shed on the development of scientific reasoning, and for the design of suitable science education activities for the elementary school.

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